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THE ROLE OF CONFORMATION TRAITS IN EVALUATING HEAT TOLERANCE IN DAIRY CATTLE

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SUMMARY

Dairy cows are highly susceptible to heat stress, and this has a detrimental effect on milk production, reproductive performance, and animal welfare. These adverse effects will grow as dairy producing regions continue to be impacted by climate change. To address this, Australia implemented a genetic evaluation for heat tolerance in 2017. The objective of this study was to assess the relationships between the heat tolerance breeding values and some conformation traits in Australian Holstein and Jersey cows. The heat tolerance slope, which is the decline in milk, fat, and protein yield as the temperature-humidity index (THI) increases was calculated using a random regression model for heat tolerance, was correlated with seven conformation traits. Angularity had the strongest genetic and phenotypic correlation with heat tolerance slope traits. However, this could be an artifact of angularity's relationship to mean milk production, as heat tolerance phenotypes and milk production traits are strongly negatively correlated. Conformation traits are related to heat tolerance proportionally to how they are related to milk yield and therefore are not good candidates proxy traits for more complex heat tolerance traits.

INTRODUCTION

Acute and chronic exposure to high ambient temperatures causes reduced milk production, reduced fertility, and increased morbidity (Hansen 2009; Wheelock *et al.* 2010; Ouellet *et al.* 2019). A recent study has shown the world has likely surpassed the 2°C threshold of the 2015 Paris agreement (Esper *et al.* 2024); the focus to help cattle adapt to warmer climate conditions is now more important than ever. In pasture-based systems, like Australia, implementing permanent, long-term mitigation strategies such as genetic selection for heat tolerance is important to ensuring continued milk production as temperatures continue to increase. Heat tolerance is defined as the cow's ability to maintain production during heat stress. Various phenotypes related to heat tolerance have been shown to be heritable such as respiratory rate, rectal temperature (Dikmen *et al.* 2012) and milk yield (Ravagnolo *et al.* 2000; Nguyen *et al.* 2016). In fact, the rate of decline in milk yield under heat stress has been used to calculate breeding values in several countries with Australia being the first to implement these in the national genetic evaluation (Nguyen *et al.* 2017). While these methods allow for genetic selection of heat tolerance, the phenotype is inextricably entwined with milk production which has a negative genetic correlation with milk yield.

Linear type classification (conformation) data provides a large repository data set within the Australian dairy cattle population. Many registered cows are classified at least once in their lifetime, providing data on the cows' physical characteristics by highly trained group of evaluators. Currently, twenty-four linear traits are measured and recorded in both the Holstein and in the Jersey classification systems.

Previous studies have reported negative genetic correlation between body depth and many health and fertility traits, and it may be inferred that body depth may have an antagonistic relationship with heat tolerance given the positive genetic correlations between heat tolerance and health traits (Haile-Mariam *et al.* 2004). In part this may be due to the increased surface area to mass ratio (SA:M) found in cattle with smaller body depth. Sensible heat loss, or the physical transfer of heat without a phase change, is thought to be dependent on an animal's surface area per unit of body weight (Hansen

2004). Brahman, *Bos indicus*, have a significantly longer epidermis than Angus, *Bos taurus*, and this may play a role in the improved heat tolerance of Brahman cattle (Mateescu *et al.* 2023). Conformation traits could be indicative of heat tolerance as they pertain to more difficult to measure phenotypes such as SA:M. This study investigated the usefulness of conformation traits to evaluate heat tolerance in Holstein and Jersey cattle.

MATERIALS AND METHODS

Conformation data. Data on 115,490 Australian Holsteins and 41,889 Australian Jerseys cows born between 1999 and 2021 were used in this study. Classification records for primiparous cows were retrieved from the DataGene database. Conformation traits, Table 1, thought to be related to heat tolerance were selected with pin set used as a comparison, given the hypothesis that it lacked relationships to any perceived biological process involved in heat tolerance. Conformation traits are scored on a linear scale of 1-9, except pin set which is scored according to biological extremes with 5 serving as the mid-point and 1 and 9 the extremes in opposite directions.

Table 1. Conformation trait record numbers, mean, and standard deviation for Holstein and Jersey cattle

Trait	Holstein			Jersey		
	No. Records	Mean	SD	No. Records	Mean	SD
Body Depth	115260	6.13	1.25	41878	6.20	0.85
Body Length	*n.a.*	*n.a.*	*n.a.*	40756	6.08	1.16
Stature	115458	6.51	1.40	41892	5.83	1.03
Chest Width	115490	5.64	1.17	41894	5.55	0.91
Pin Width	115490	6.30	1.27	41879	5.50	0.94
Angularity	115490	5.89	1.15	41843	6.58	0.85
Pin Set	115490	4.09	1.30	41889	5.34	0.83

Production Data. For each cow, the slope (HTS) and intercept (HTI) of the random regression model for milk, fat, and protein yield as THI increases were calculated as per the current Australian breeding value for heat tolerance described in Nguyen et al. (2016). The model includes the second-order orthogonal polynomial THI interacting with a fixed regression coefficient of milk, fat, or protein yield on THI and the random regression coefficient on heat load in addition to several fixed effects to account for environmental variability. Temperature-humidity index (THI) was calculated using the equation: $THI = T_{db} + 0.36T_{dp} + 41.2$, where T_{db} is dry-bulb temperature and T_{dp} is dew-point temperature (Yousef 1985).

Statistical analysis. A tri-variate pedigree-based REML analysis was used to calculate the genetic and phenotypic correlations between each of the conformation traits and heat tolerance slope (HTS) and heat tolerance intercept (HTI) traits. The variance components were estimated using ASReml (v. 4.2.1) fitting an animal model. HTS and HTI for milk, fat, and protein yields were both adjusted for year-season of calving. Confirmation traits were adjusted for age at classification, days in milk at classification, and the classifier-round by herd effect by including them in an animal model analysis.

RESULTS AND DISCSSION

The genetic correlations between HTS milk and the conformation traits ranged from -0.01 (chest width) to -0.26 (angularity) in Holsteins (Table 2) and 0.01 (chest width) and -0.38 (angularity) in Jerseys (Table 3). The genetic correlations between conformation traits and HTS fat or HTS protein were similar to HTS milk in Holsteins. However, in Jersey, the genetic correlations between conformation traits and HTS fat or HTS protein were greater than HTS milk. Body depth had a genetic correlation of -0.15 with HTS milk and -0.25 with HTS fat (Table 3). Perhaps this is due to Jerseys producing more fat and protein in the milk; therefore, reduced energy consumption from heat stress effects milk composition more than volume for Jerseys.

The genetic correlations between HTI milk and the conformation traits ranged from 0.01 (chest width) and 0.23 (angularity) for Holstein and from 0.02 (chest width) and 0.37 (angularity) for Jerseys (not presented). These results align with the negative genetic correlations between HTI and HTS of -0.96, --.97, and -0.97 for Holsteins and of -0.97, -0.99, -0.98 for Jerseys for milk, fat, and protein respectively.

Table 2. Conformation trait heritability and genetic correlation with Heat Tolerance Slope for Holstein cows

Trait	h^2	Milk r_g*	Fat r_g	Protein r_g
Body Depth	0.27	-0.13 ± 0.03	-0.17 ± 0.03	-0.11 ± 0.03
Stature	0.34	-0.16 ± 0.03	-0.11 ± 0.03	-0.20 ± 0.03
Chest Width	0.17	-0.01 ± 0.04	-0.05 ± 0.04	-0.04 ± 0.04
Pin Width	0.29	-0.17 ± 0.03	-0.15 ± 0.03	-0.18 ± 0.03
Angularity	0.17	-0.26 ± 0.03	-0.27 ± 0.04	-0.24 ± 0.04
Pin Set	0.33	-0.05 ± 0.03	0.01 ± 0.03	-0.03 ± 0.03

* r_g = genetic correlation

Table 3. Conformation trait heritability and genetic correlation with Heat Tolerance Slope for Jersey cows

Trait	h^2	Milk r_g*	Fat r_g	Protein r_g
Body Depth	0.23	-0.15 ± 0.03	-0.25 ± 0.03	-0.18 ± 0.03
Body Length	0.26	-0.19 ± 0.03	-0.25 ± 0.03	-0.25 ± 0.03
Stature	0.37	-0.18 ± 0.03	-0.28 ± 0.03	-0.25 ± 0.03
Chest Width	0.14	0.02 ± 0.04	-0.18 ± 0.04	-0.07 ± 0.04
Pin Width	0.19	-0.13 ± 0.04	-0.24 ± 0.04	-0.20 ± 0.04
Angularity	0.20	-0.37 ± 0.03	-0.33 ± 0.4	-0.38 ± 0.04
Pin Set	0.27	-0.06 ± 0.03	-0.06 ± 0.03	-0.06 ± 0.03

* r_g = genetic correlation

The relationship between HTS and conformation traits in this study indicates that conformation traits had weak to moderate relationships with heat tolerance traits in both Holstein and Jersey cows, and the strongest correlations were obtained with angularity (range: -0.24 to -0.38) (Table 2 and 3). Angularity describes the angle, openness, and spring of rib that cattle possess with the ideal rib having adequate spacing between the ribs, angled back from the chest towards the flank, and springing out from the vertebrae when viewed from behind. The negative correlation with HTS indicates that more angular cows are more susceptible to the effects of heat stress. Given the positive genetic correlation of 0.48 between angularity and milk yield (Berry *et al.* 2004), the relationship between HTS and angularity could simply be a by-product of the relationship with milk production. This could be tested using the HTS adjusted for HTI (heat tolerance independent from milk production). Despite evidence of body size differences impacting heat tolerance in beef cattle, this may largely be due to differences between *Bos indicus* and *Bos taurus* animals or different breeds (Mateescu *et al*. 2023; Madhusoodan *et al*. 2019). Given that dairy cattle selection mainly happens within breed, conformation trait differences may not have enough genetic variation to be strong indicators of HTS. Moreover, milk production and the associated metabolic heat production are strongly correlated with many conformation traits, and that relationship may be stronger than that between conformation traits and heat tolerance mechanisms.

CONCLUSION

Angularity had the greatest genetic correlation with heat tolerance slope, -0.24 and -0.38 with in Holstein and Jersey respectively. Considering there was only low to medium correlation between heat tolerance and conformation traits and that this is possible an indirect influence of milk production, the conformation traits are not deemed good candidates to use as a proxy trait for heat tolerance. These results also show that the selection for conformation traits or HTS does have any intended negative effect.

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